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**Original Research Article**

# Emergence hemodynamic changes and postoperative outcomes in hypertensive patients receiving antihypertensive therapy undergoing general anesthesia: an observational study

**Nahin Mahmud[1]*, Debabrata Banik[2], Ahsan Habib Khan[3], Nazmul Huda Naim[4], M. Fahad[5]**

[1]Department of Anesthesia and ICU, Enam Medical College Hospital, Savar, Dhaka, Bangladesh
[2]Department of Anesthesia, Analgesia and Intensive Care Medicine, Bangladesh Medical University, Dhaka, Bangladesh
[3]Department of Anesthesia, Shaheed Tajuddin Ahmad Medical College Hospital, Gazipur, Bangladesh
[4]Department of Anesthesia, Khokon Memorial Hospital, Sirajgonj, Bangladesh
[5]Department of Anesthesia, BRB Hospitals Limited, Dhaka, Bangladesh

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***Correspondence:**
Dr. Nahin Mahmud,
E-mail: nahinmahmud91@gmail.com



## ABSTRACT

**Background:** Hypertensive patients undergoing general anesthesia often continue antihypertensive therapy through the perioperative period, yet whether the number of preoperative antihypertensive agents predicts the need for intraoperative anesthetic modulation or postoperative outcome remains unclear. This study aimed to characterise antihypertensive medication burden, anesthetic modulation requirement and postoperative adverse events in hypertensive patients undergoing general anesthesia.
**Methods:** This prospective observational study enrolled 60 diagnosed hypertensive patients undergoing elective surgery at Bangladesh Medical University, Dhaka, over twelve months. Patients were grouped as normotensive, hypotensive or hypertensive according to intraoperative blood pressure deviation from baseline. Number of antihypertensive medications, frequency of anaesthetic modulation, systolic, diastolic and mean arterial pressures according to medication count and postoperative adverse events were recorded and analyzed using SPSS version 26.0.
**Results:** Single-drug therapy was used by 63.3% of patients, two-drug combinations by 23.3% and three or more drugs by 13.4%. Hypotensive patients most often required two episodes of anesthetic modulation (50.0%), while hypertensive patients most often required three (63.0%). Blood pressure did not differ significantly by medication count at any time point ($p>0.05$). Postoperative nausea and vomiting occurred in 50% of hypertensive, 33.3% of hypotensive and 9.3% of normotensive patients ($p=0.007$) and coughing occurred only in hypertensive patients (25%, $p=0.003$).
**Conclusions:** Antihypertensive medication count did not predict perioperative hemodynamic instability, whereas intraoperative blood pressure status was strongly associated with modulation requirement and postoperative adverse events.

**Keywords:** Anesthetic modulation, Antihypertensive agents, General anesthesia, Hypertension, Perioperative care, Postoperative complications

## INTRODUCTION

Perioperative management of the hypertensive surgical patient is complicated by the question of whether and how, established antihypertensive therapy should be continued through the operative period. Avoidance of wide swings in heart rate and blood pressure, toward either hypotension or hypertension, is central to minimizing the substantial risk of major perioperative cardiac morbidity that hypertensive patients face.[1] Yet the pharmacological agents used to control blood pressure preoperatively do not simply disappear from the physiological picture once a patient

enters the operating theatre; several drug classes interact directly with the hemodynamic effects of anesthetic induction and maintenance.

Renin-angiotensin system antagonists, including angiotensin-converting enzyme inhibitors and angiotensin receptor blockers, have been repeatedly implicated in refractory intraoperative hypotension when continued up to the morning of surgery, an interaction attributed to blockade of the compensatory vasoconstrictive response that normally offsets anesthetic-induced vasodilatation.[2] Omission of regular ACE inhibitor therapy before surgery has similarly been shown to alter intraoperative hemodynamic variables and vasoactive drug requirements.[3] These observations have shaped joint guidance from anesthesia and hypertension societies, which now recommend a nuanced, drug-class-specific approach to perioperative continuation of antihypertensive therapy rather than a uniform policy of withholding or continuing all agents.[4]

Current hypertension management guidelines increasingly favour combination pharmacotherapy over monotherapy to achieve target blood pressure control, particularly in patients with higher baseline readings or additional cardiovascular risk factors.[5] As a consequence, anaesthetists are progressively more likely to encounter surgical patients maintained on two or more antihypertensive agents rather than a single drug, a shift that raises practical questions about whether the number of preoperative agents itself predicts the degree of intraoperative hemodynamic instability, or the extent of anesthetic modulation, such as supplementary vasopressor or antihypertensive dosing, required to keep blood pressure within acceptable limits.[6]

The physiological rationale for expecting such an association is plausible: patients receiving more intensive antihypertensive therapy may have more severe or longer-standing hypertensive vascular disease, a state associated with impaired baroreceptor sensitivity and greater blood pressure lability under anesthesia.[7] Equally, however, effective multidrug control might be expected to produce a more stable perioperative course than poorly controlled monotherapy, so the direction of any relationship is not obvious from first principles and existing perioperative cardiovascular guidelines offer no unified position on this question.[8]

Beyond intraoperative hemodynamics, the number and type of antihypertensive agents used, together with the degree of anesthetic modulation required to manage blood pressure deviation, may also carry implications for postoperative recovery, including the incidence of adverse events such as postoperative nausea and vomiting, bradycardia, tachycardia and laryngospasm, all of which have been described at elevated rates in surgical patients with unstable perioperative hemodynamics.[9,10] Despite the frequency with which anaesthetists manage patients on combination antihypertensive regimens, few observational studies have directly examined whether the burden of preoperative antihypertensive therapy, the requirement for intraoperative anesthetic modulation and postoperative adverse event rates are meaningfully related within a single hypertensive surgical cohort.[11]

This study was therefore designed to characterise the antihypertensive medication burden, the frequency of anesthetic modulation and the pattern of intraoperative blood pressure and postoperative adverse events in a cohort of diagnosed hypertensive patients undergoing elective surgery under general anesthesia, with the aim of clarifying whether the intensity of preoperative antihypertensive therapy meaningfully predicts intraoperative hemodynamic behaviour or postoperative course.[12]

## METHODS

This prospective observational study was conducted in the operation theatres under the department of anesthesia, Analgesia and Intensive Care Medicine, Bangladesh Medical University, Dhaka, Bangladesh, from April 2024 to March 2025. The study population comprised sixty diagnosed hypertensive patients already established on antihypertensive medication who were admitted for elective surgery under general anesthesia requiring endotracheal intubation, identified and enrolled during routine pre-anesthetic assessment.

### *Inclusion criteria*

Known and diagnosed hypertensive patients on antihypertensive medication undergoing elective surgery under general anesthesia requiring endotracheal intubation. Age between 31 and 65 years. Weight between 40 and 75 kg. ASA physical status class II or class III. Mallampati class I or class II airway. Surgery of more than one and less than three hours duration.

### *Exclusion criteria*

ASA physical status class IV or above. Severe systemic disease, including high-risk cardiac conditions (severe valvular heart disease, symptomatic congenital heart disease, heart failure), or significant pulmonary, renal or hepatic disease. Morbid obesity. Pregnancy. Documented hypersensitivity to anesthetic agents required for general anesthesia.

### *Study procedure*

Patients continued their routine antihypertensive medications up to and including the morning of surgery and received 7.5 mg of oral midazolam as premedication. Standard monitoring was established on arrival in the operating theatre and anesthesia was induced with intravenous fentanyl, propofol and suxamethonium, then maintained with isoflurane in a nitrous oxide-oxygen mixture with mechanical ventilation and incremental

vecuronium. The number and class of preoperative antihypertensive medications was recorded for each patient and categorized as single-drug, two-drug combination, or combination of more than two drugs. Intraoperatively, deviations in blood pressure exceeding 20% from baseline were managed according to standard protocol using intravenous ephedrine for hypotension or intravenous labetalol and nitroglycerine for hypertension and every episode requiring such pharmacological intervention was recorded as one instance of anesthetic modulation. Systolic, diastolic and mean arterial pressures were captured at baseline, before induction, before extubation and at defined intervals after extubation and postoperative adverse events, including nausea, vomiting, bradycardia, tachycardia, laryngospasm and coughing, were documented over a six-hour observation period in the post-anesthesia care unit.

### *Ethical consideration*

Institutional review board approval was obtained from Bangladesh Medical University before the study commenced. Written informed consent was secured from every participant after the purpose, procedures and potential risks and benefits of the study were explained in accessible language and all participants were informed of their unrestricted right to withdraw at any point without consequence to their clinical management. Confidentiality was maintained through coded data records, restricted access and secure storage throughout the study period.

### *Statistical analysis*

Data were compiled into a master chart and analyzed using the Statistical Package for Social Sciences (SPSS), version 26.0 for Windows. Categorical variables were summarized as frequencies and percentages and compared using the chi-square test, while continuous variables were summarized as mean±standard deviation and compared across groups using one-way analysis of variance (ANOVA). A p value of less than 0.05 was regarded as statistically significant for all analyses.

## RESULTS

Sixty diagnosed hypertensive patients on antihypertensive therapy were analyzed, allocated by intraoperative blood pressure behaviour into normotensive (group N, n=32), hypotensive (group H, n=12) and hypertensive (group P, n=16) groups.

Table 1 presents the baseline demographic and clinical characteristics of the study population. The age distribution of 60 patients across different groups, with a mean age of 50.3±7.5 years. The weight distribution of 60 patients, with a mean weight of 56.7±5.4 kg. Among the study population, 62% of the participants were male, while 38% were female. The majority (71.7%) were classified as ASA class II, indicating the presence of mild systemic disease. The remaining 28.3% were categorized as ASA class III, representing patients with severe systemic disease.

**Table 1: Baseline demographic and clinical characteristics of the study population (n=60).**

| Characteristics | | Value (%) |
|---|---|---|
| **Age, years (mean±SD)** | | 50.3±7.5 |
| **Weight, kg (mean±SD)** | | 56.7±5.4 |
| **Gender** | Male | 37 (61.7) |
| | Female | 23 (38.3) |
| **ASA Class II** | | 43 (71.7) |
| **ASA Class III** | | 17 (28.3) |

ASA, American Society of Anesthesiologists physical status classification.

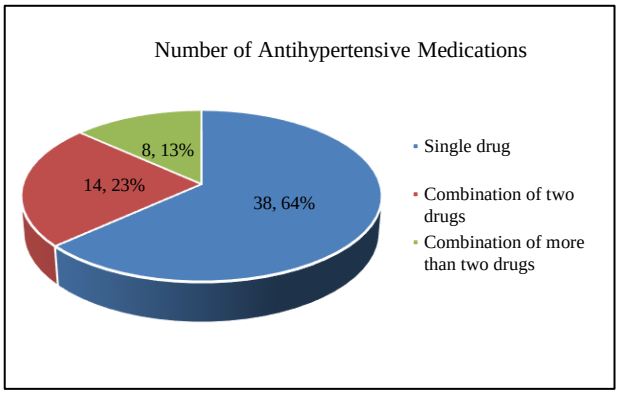


**Figure 1: Distribution of patients according to antihypertensive medications.**

Figure 1 presents the distribution of patients according to the number of antihypertensive medications. The majority of the patients take a single drug (64%). 23% of patients take a combination of two drugs and 13% of patients take a combination of more than two drugs.

**Table 2: Distribution of patients according to number of antihypertensive medications among the three groups.**

| Number of drugs | Group N (n=32) | Group H (n=12) | Group P (n=16) |
|---|---|---|---|
| **Single drug** | 18 (56.3) | 8 (66.7) | 12 (75.0) |
| **Combination of two drugs** | 9 (28.1) | 3 (25.0) | 2 (12.5) |
| **Combination of more than two drugs** | 5 (15.6) | 1 (8.3) | 2 (12.5) |

Values are expressed as frequency (%) over column total.

Table 2 shows that single drug therapy was the most common treatment, particularly in hypertensive patients (75%). Two drug combinations were less frequently used, especially in hypertensive cases. Use of more than two drugs was minimal across all groups, with the lowest in hypotensive patients (8.3%).

**Table 3: Distribution of patients according to the requirement for intraoperative anesthetic modulation.**

| Number of modulation episodes | Group H (n=12) (%) | Group P (n=16) (%) |
|---|---|---|
| **1 time** | 1 (8.3) | 0 (0.0) |
| **2 times** | 6 (50.0) | 3 (18.5) |
| **3 times** | 4 (33.4) | 10 (63.0) |
| **4 times or more** | 1 (8.3) | 3 (18.5) |

Table 3 shows that hypotensive patients (group H) most commonly required two modulations (50.0%), whereas hypertensive patients (group P) most often required three modulations (63.0%). Single modulations were rare in both groups and four or more modulations were needed by only a small minority.

Table 4 compares the duration of antihypertensive drug use, anesthesia duration, surgery duration and extubation time among the groups. The durations of antihypertensive drug use, anesthesia and surgery showed no significant differences among the groups ($p>0.05$). However, extubation time was longer in group H and group P compared to group N, which is statistically significant ($p<0.05$).

**Table 4: Duration of antihypertensive therapy, anesthesia, surgery and extubation among the three groups.**

| Variables | Group N (n=32) | Group H (n=12) | Group P (n=16) | P value |
|---|---|---|---|---|
| **Duration of antihypertensive therapy (years)** | 5.5±2.1 | 5.2±2.6 | 4.9±2.0 | 0.091 |
| **Anaesthesia duration (minutes)** | 147.3±20.1 | 158.7±29.4 | 161.5±20.6 | 0.797 |
| **Surgery duration (minutes)** | 137.5±20.8 | 141.2±20.1 | 139.3±22.2 | 0.611 |
| **Extubation time (minutes)** | 3.5±0.4 | 4.7±0.5 | 4.8±0.8 | 0.001* |

Values are expressed as mean±SD. P determined by one-way ANOVA. *Statistically significant ($p<0.05$).

**Table 5: Comparison of systolic blood pressures according to number of antihypertensive medications.**

| Intervals | Single (n=38) | Two drugs (n=14) | >Two drugs (n=8) | P value |
|---|---|---|---|---|
| **Baseline** | 138.8±6.2 | 139.8±6.4 | 136.4±8.9 | 0.514 |
| **Before induction** | 142.5±5.7 | 143.6±6.8 | 139.4±8.9 | 0.325 |
| **Just before extubation** | 146.5±26.8 | 144.6±23.4 | 145.8±26.3 | 0.974 |
| **Just after extubation** | 154.1±27.5 | 152.6±23.4 | 153.8±26.3 | 0.985 |
| **5 minutes after extubation** | 149.1±27.5 | 147.6±23.4 | 149.5±24.6 | 0.982 |
| **10 minutes after extubation** | 144.9±27.3 | 143.4±23.0 | 145.7±26.2 | 0.97 |
| **15 minutes after extubation** | 141.0±26.8 | 140.9±22.8 | 142.9±25.4 | 0.981 |

**Table 6: Comparison of diastolic blood pressures according to number of antihypertensive medications.**

| Intervals | Single (n=38) | Two drugs (n=14) | >Two drugs (n=8) | P value |
|---|---|---|---|---|
| **Baseline** | 88.0±5.2 | 87.3±6.7 | 86.4±6.2 | 0.854 |
| **Before induction** | 91.0±5.1 | 90.3±6.7 | 89.3±6.1 | 0.804 |
| **Just before extubation** | 93.6±20.9 | 91.7±19.5 | 92.2±20.3 | 0.951 |
| **Just after extubation** | 102.7±21.6 | 100.6±20.4 | 101.5±20.7 | 0.954 |
| **5 minutes after extubation** | 97.7±21.3 | 95.7±20.4 | 96.4±20.8 | 0.954 |
| **10 minutes after extubation** | 92.7±20.2 | 90.7±19.8 | 91.5±19.7 | 0.974 |
| **15 minutes after extubation** | 87.8±20.0 | 85.7±19.6 | 86.7±19.5 | 0.985 |

**Table 7: Comparison of mean arterial pressures according to number of antihypertensive medications.**

| Intervals | Single (n=38) | Two drugs (n=14) | >Two drugs (n=8) | P value |
|---|---|---|---|---|
| **Baseline** | 105.7±5.0 | 106.0±6.6 | 104.2±7.7 | 0.776 |
| **Before induction** | 109.1±5.0 | 109.5±6.6 | 107.5±7.8 | 0.718 |
| **Just before extubation** | 114.9±22.5 | 112.6±20.1 | 114.1±23.1 | 0.968 |
| **Just after extubation** | 120.8±23.0 | 118.6±20.1 | 119.9±23.3 | 0.975 |
| **5 minutes after extubation** | 116.8±23.0 | 113.6±20.0 | 114.1±22.5 | 0.966 |
| **10 minutes after extubation** | 112.9±20.1 | 110.9±22.6 | 110.4±20.4 | 0.925 |
| **15 minutes after extubation** | 107.4±17.8 | 106.6±13.4 | 107.2±17.4 | 0.991 |

Values are expressed as mean±SD. P determined by one-way ANOVA. No between-group difference reached statistical significance at any interval.

**Table 8: Comparison of postoperative adverse events among the three groups.**

| Events | Group N (n=32) | Group H (n=12) | Group P (n=16) | P value |
|---|---|---|---|---|
| **Postoperative nausea and vomiting** | 3 (9.3) | 4 (33.3) | 8 (50.0) | 0.007* |
| **Bradycardia** | 0 (0.0) | 3 (25.0) | 2 (12.5) | 0.022* |
| **Tachycardia** | 3 (9.3) | 1 (8.3) | 0 (0.0) | 0.455 |
| **Laryngospasm** | 1 (3.1) | 3 (25.0) | 1 (6.2) | 0.061 |
| **Coughing** | 0 (0.0) | 0 (0.0) | 4 (25.0) | 0.003* |

Values are expressed as frequency (%) over column total. P determined by chi-square test. *statistically significant (p<0.05).

Table 5 compares the mean systolic blood pressure (SBP) among patients receiving a single antihypertensive drug, a combination of two drugs and a combination of more than two antihypertensive drugs at different time intervals. Patients on a single antihypertensive drug had slightly higher mean SBP compared to those on a combination of two or more drugs. However, the difference was not statistically significant (p>0.05).

Table 6 compares the mean diastolic blood pressure (DBP) among patients who were on a single antihypertensive drug, a combination of two drugs, and a combination of more than two drugs at various time points: baseline, before induction, just before extubation, just after extubation, and at 5, 10, and 15 minutes after extubation. Patients on a single antihypertensive drug had a higher mean DBP compared to those on two or more drugs, but the difference was not statistically significant (p>0.05).

Table 7 compares the mean arterial pressure (MAP) among patients on a single antihypertensive drug, a combination of two drugs and a combination of more than two drugs at various time points: baseline, before induction, just before extubation, just after extubation and at 5, 10 and 15 minutes after extubation. No statistically significant difference was observed among the groups (p>0.05).

The incidence of laryngospasm was 3.1% in group N, 25% in group H and 6.2% in group P. Tachycardia occurred in 9.3% of group N and 8.3% of group H. No statistically significant difference was observed among the three groups, as the p value was >0.05. In group H, 25% had bradycardia, while in group P, 12.5% of patients experienced it. The incidence of PONV was highest in group P (50%), followed by group H (33.3%) and group N (9.3%). Coughing occurred in 25% of group P. These findings were statistically significant, with a p value <0.05 (Table 8).

## DISCUSSION

In the present cohort, single-drug antihypertensive therapy was the most frequently used regimen, accounting for 63.3% of patients overall, followed by combination therapy with two drugs in 23.3% and three or more drugs in 13.4%, a pattern broadly comparable with the therapy distribution reported by Shailaja and Srikantu in a similarly constituted hypertensive surgical population.[13] Single-drug therapy was particularly common among patients who subsequently developed intraoperative hypertension, seen in 75% of this group, a finding that may reflect relative intravascular volume depletion and heightened vascular resistance characteristic of chronic hypertensive physiology even when blood pressure appears adequately controlled on a single agent, suggesting that monotherapy alone may be an imperfect marker of true perioperative hemodynamic stability.[14]

The requirement for intraoperative anesthetic modulation differed markedly between the hypotensive and hypertensive groups. Patients who developed intraoperative hypotension most commonly required two episodes of modulation (50.0%), whereas those who developed intraoperative hypertension most often required three (63.0%), with four or more episodes needed by a minority of patients in each group. This pattern indicates that hypertensive excursions during the intraoperative period were, on average, more resistant to single-dose correction than hypotensive excursions, consistent with the broader observation that acute intraoperative hypertension often reflects a combination of surgical stimulation, inadequate anesthetic depth and pre-existing vascular stiffness rather than a single readily correctable cause.[15]

Duration of antihypertensive drug use, anesthesia and surgery itself did not differ significantly between the normotensive, hypotensive and hypertensive groups (p>0.05 for all three variables), indicating that the observed intraoperative blood pressure instability was not simply a function of longer surgical exposure or more prolonged anesthetic time. Extubation time, by contrast, was significantly longer in both the hypotensive (4.7±0.5 minutes) and hypertensive (4.8±0.8 minutes) groups compared with the normotensive group (3.5±0.4 minutes, p=0.001), suggesting that hemodynamic instability itself, rather than procedural duration, was the more relevant determinant of delayed emergence.

When systolic, diastolic and mean arterial pressures were compared according to the number of antihypertensive medications rather than intraoperative blood pressure status, no statistically significant differences emerged at any time point, including the pre-extubation and post-extubation intervals (p>0.05 throughout). The present findings suggest that the number of antihypertensive medications used preoperatively was not significantly

associated with the magnitude of intraoperative or emergence- related blood pressure fluctuations. This observation is consistent with the established concept that effective blood pressure control, rather than the number of pharmacological agents required to achieve it, is the primary determinant of perioperative hemodynamic stability.[7] This is a clinically useful negative finding, since it suggests that anaesthetists need not anticipate greater hemodynamic instability in patients on multidrug antihypertensive regimens purely on the basis of medication count.

Postoperative adverse events were unevenly distributed across the three groups. Postoperative nausea and vomiting occurred in half of the hypertensive group, compared with 33.3% of the hypotensive group and only 9.3% of the normotensive group (p=0.007), while bradycardia was documented in a quarter of hypotensive patients and 12.5% of hypertensive patients (p=0.022). Coughing during the immediate recovery period occurred exclusively in the hypertensive group, affecting a quarter of these patients (p=0.003). Kellner et al similarly reported that hemodynamic instability in the post-anesthesia care unit is closely linked to a wider range of adverse recovery events and Zivanovic et al described comparable clustering of adverse hemodynamic and recovery events around tracheal extubation specifically in hypertensive patients.[9,16] The association between intraoperative blood pressure derangement, whether hypertensive or hypotensive and adverse postoperative outcome has also been documented outside the immediate recovery period, with van Waes et al and Walsh et al linking intraoperative hypotension to myocardial injury after non-cardiac surgery and Bijker et al demonstrating an association between intraoperative hypotension and one-year mortality.[17-19] Although the present study did not follow patients beyond the immediate six-hour postoperative window, the clustering of adverse events observed in both the hypotensive and hypertensive groups reinforces the broader principle, also reflected in current extubation guidelines, that careful individualized planning around the timing and technique of tracheal extubation is warranted in hypertensive surgical patients regardless of their preoperative medication regimen.[20] Taken together, these findings suggest that while antihypertensive medication count alone offers limited prognostic value, the pattern of intraoperative blood pressure deviation itself is a more informative marker of postoperative adverse event risk and should be incorporated into individualized perioperative planning for hypertensive surgical patients.[9]

A principal limitation of this study was variability in the non-invasive blood pressure measurement devices used across patients, which may have introduced minor inconsistency in recorded values, together with its single-center design, which may limit generalizability. Future multicenter studies using standardized monitoring equipment and extended postoperative follow-up are recommended to confirm these findings and to determine whether specific antihypertensive drug classes, rather than medication count alone, better predict perioperative hemodynamic behaviour and adverse outcome in hypertensive surgical patients.

## CONCLUSION

Antihypertensive medication count did not significantly predict intraoperative or emergence blood pressure behaviour in this hypertensive surgical cohort, whereas intraoperative blood pressure status itself, whether hypertensive or hypotensive, was strongly associated with the requirement for anesthetic modulation and with postoperative adverse events including nausea, vomiting, bradycardia and coughing. Hypertensive patients required more frequent anesthetic modulation than hypotensive patients and experienced the highest rate of postoperative nausea and vomiting. These findings support individualized perioperative planning based on observed intraoperative hemodynamic behaviour rather than preoperative medication regimen alone, with particular attention to anesthetic modulation strategy in patients who develop intraoperative hypertension.

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